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CELESTIAL PHOTOGRAPHS.

Photographs of Stars, Star-clusters and Nebulae, together with Records of Results obtained in the pursuit of Celestial Photography. By Isaac Roberts, D.Sc., F.R.S. Vol. ii. Pp. 178. Plates. (London: *Knowledge* Office, 1900.)

IT is now nearly six years ago since Dr. Roberts published his first volume on celestial photographs, which was noticed at some length in these columns (vol. l. p. 447). It was there remarked that the volume was the result of a "remarkable example of what can be done single-handed in a new line of research," and we might echo the same statement as regards the contents of the present issue.

Every astronomical reader is familiar with the first publication; indeed, Dr. Roberts's celestial photographs of long exposure were, and still are, so remarkable that many of them have been reproduced in most of the more recent works on astronomy. It is interesting to remark that in commencing astronomical photography it was the author's original intention to make a photographic chart of the sky between the north pole and the equator, so that those who came after him could, by taking similar photographs and comparing them with his, detect any changes that might have taken place during the interval that had elapsed. After he had secured many photographs on a definite programme of work, the international scheme for making a photographic chart of the whole heavens was suggested and commenced under the direction of the late Admiral Mouchez. Dr. Roberts therefore discontinued his charting work, and began the important investigation of photographing, on a large scale and with long exposures, the various star-clusters and nebulæ with the object of securing exact pictures of them, so that any changes that might take place in them might be detected after the lapse of some years.

The first volume indicated to the astronomical world the great and well deserved success which rewarded the labours of Dr. Roberts in this, perhaps, the most interesting branch of astronomy, and he may be said to have continued with the photographic plate the work that the Herschels accomplished visually with their giant telescopes. Like these celebrated observers, he has photographed "double and treble nebulæ variously arranged: large ones, with small, seeming attendants; narrow, but much extended, lucid nebulæ and bright dashes; some of the shape of a fan, resembling an electric brush, issuing from a lucid point; others of a cometic shape, with a seeming nucleus in the centre, or like cloudy stars surrounded with a nebulous atmosphere; a different sort, again, contains a nebulosity of a different kind, ...; while others shine with a fainter, mottled kind of light, which denotes their being resolvable into stars."

Of the seventy-two objects enlarged from the original negatives, and here beautifully reproduced in collotype by the London Steroscopic Company, thirty-three are of spiral nebulæ, fifteen of clusters, fourteen of nebulæ, irregular and cloudlike in form, six of crowded star areas, and four of annular nebulæ. The original photographs which are 15 centimetres square, were all obtained, as formerly, with the silver on glass reflector of 20 inches aperture and 98 inches focal length. It may be here mentioned that Dr. Roberts has added to his instrumental equipment a specially made Cooke triplet portrait lens of 5 inches aperture and 19·22 inches focal length, with a photographic field of 15 degrees diameter.

In the work before us, the arrangement of the plates differs from that adopted in the first volume. The photographs, instead of following each other in the order of right ascension, are here divided into classes or groups, each of which indicates apparent physical relationships, and the members of each group are arranged as far as practicable in the order of right ascension. The scale of enlargement is given in each case, as well as a table for converting the measured right ascensions of the stars shown on the photographs into intervals of time for each degree in declination. It may be remarked that the table of corrections to be applied to the scales of the photo-plates which appeared in the first volume has been dispensed with, owing no doubt to the improvement in the manufacture of photographic films. The co-ordinates of each of the fiducial stars are given for the epoch 1900, and on the plates these stars are marked with dots as formerly.

In the reproduction of such difficult objects as those here illustrated, it is well known that much fine detail is lost in the process. Reproductions, although approximating closely, yet never come up to the quality of the original negatives. The last mentioned, however, are subject to many vicissitudes. They can become broken, the films become discoloured after some time, images fade, and faint nebulosities disappear entirely. That such is the case is clearly proved by the experience of Dr. Roberts, which is related in his introduction.

To mention only one instance of many, he tells us how, shortly after a photograph of a certain region of the sky was taken (in February 1886), he counted 403 star images on the negative. On May 29, 1895, or after an interval of nine and a quarter years, no less than 131 stars had disappeared from the same plate, he being only able to count 272 images.

With such facts before us, it is therefore of great importance that as each negative is secured an impression of it should be made in permanent form, such as in printer's ink. If the work be done well, as is the case with the beautiful illustrations in this volume, future astronomers will have valuable data at their disposal for making direct comparisons.

In the introduction, Dr. Roberts refers to several points of great interest, which will be read generally with advantage, but especially by those who expose their plates to the sky for long intervals of time. He first gives us an account of his experiments regarding the effect of "atmospheric glare," which is due to starlight, causing a general fogging of the whole photographic plate. For exposures extending over several hours, Dr. Roberts is led to deduce that, at any rate for this country at least, by the time that the image of an eighteenth magnitude star is well impressed on the photographic plate, the whole plate has become so

generally fogged that the density of a star of the nineteenth magnitude, or of even nebulosity of the same brightness, is not distinguishable. This glare, therefore, apparently places a limit on the photographic penetrative power of the instrument employed, and, as far as Dr. Roberts's conditions of observation are concerned, the limit for luminosity of the feebleness of about the eighteenth magnitude is reached. Perhaps for such a clear atmosphere as is experienced at Arequipa, in Peru, and like stations, and with instruments of larger aperture, even fainter stars might be reached. This is a subject, however, which requires considerable research before any very definite statement can be accurately made.

The next point dealt with is perhaps the most important of all. It is the general impression that if a photographic plate be exposed in a telescope for several hours, it will, on development, show more stellar images than if it had been exposed for one hour; indeed, the longer the exposure, the more detail will be impressed on the photographic plate, and one can quite imagine that if exposure were sufficiently long, the whole plate would be covered with images, indicating that we are practically surrounded by a wall of stars.

This, however, is not the case according to the investigations of Dr. Roberts, and he produces very strong evidence in his favour. If two exposures be made on one object, say, one lasting one and one-half hours, and another for twelve hours, and should the same amount of detail be depicted on each, the natural deduction would be that the longer exposure did not show any more detail than the shorter one, because there would be no more images to record. From a minute examination of photographs of the great nebula in Andromeda, in Orion, the group of the Pleiades, and the region of the Milky Way about Cygnus, Dr. Roberts finds that such is the case, and that lengthened exposure need not necessarily mean an increased number of stellar images. He is thus led to accept the fact as a demonstration "of the accuracy of the surmises of astronomers in the past, that the part of the starry universe visible from the earth is limited in extent, and that notwithstanding the enormous assistance afforded by the photographic method, we are again brought to a check because of the inadequacy of the powers we possess to enable us to peer beyond that part of space in the midst of which we are placed. . . ."

It would be interesting to inquire whether Dr. Roberts has examined other photographs of these regions taken by different observers who have also employed long exposures and other instruments, and, if so, whether his opinion as regards this point has been endorsed. Such an examination as here suggested might lend additional strength to the conclusion he has already drawn.

In directing attention to the evolution of stellar systems, the author places before his readers a series of beautiful illustrations of his plates showing rich fields of stars of various degrees of condensation; spiral nebulæ varying as regards symmetry; circular, annular and irregular nebulæ; and lastly, nebulæ of a cloud-like nature, which cover enormous areas and are conspicuous by their great irregularity. The wonderful groupings into lines and curves of many of the stars in these clusters and nebulæ, and the forms of the nebulous matter, leave, as Dr. Roberts points out, no room for doubt that they are the effects of physical causes, and, on account of their persistency on the plates, are very improbably due to coincidence only. The author further differentiates between those stars which are actually involved in nebulæ, and those which are situated simply in the line of sight, but do not conform with the trend of the spirals or with the curves of the nebulous stars involved in them.

Many other points of interest are referred to in these pages, among which we may mention the variability and motion of nebulæ; these and others, however, we must leave to those of our readers who have the good fortune to examine the volume for themselves.

In the publication of this work, Dr. Roberts has not only nobly enriched astronomical science, but has raised a monument to himself which will last as long as astronomy has any interest for mankind. This handsome book, besides being a most valuable mine of information, serves not only as a demonstration of the success that has rewarded his efforts after an infinite amount of most skilful instrumental adjustment and working, but as an excellent example of the valuable work that can be accomplished single-handed when one is endowed with both the love for and the means of studying the oldest of the sciences. WILLIAM J. S. LOCKYER.

TWO MONSTROUS REPTILES.

(1) *A Complete Mosasaur's Skeleton and* (2) *A Skeleton of Diplodocus.* Being Parts iv. and v. of vol. i. of "Memoirs" of the American Museum of Natural History. By H. F. Osborn. With 8 Plates and 28 Text Illustrations. (New York: The Knickerbocker Press, 1899.)

THE memoirs above-mentioned are the latest of a series which, though not yet in their second volume, have already taken their place in the foremost rank of zoological publications. For this praiseworthy result the world is largely indebted to the author of the present memoirs, through his great monograph on "The Extinct Rhinoceroses"—the third in order of succession to appear. That came to those cognisant of his rich resources and familiar with his former doings as the fulfilment of a desire, and in itself set a high standard of excellence. In the memoirs under review this has been fully maintained, both as regards text and illustrations, which are alike highly finished works of art, worthy a pupil of Huxley. The two sets of remains dealt with are equally remarkable—one for the fact that parts usually lost by decomposition after death are here preserved; the other as furnishing us, for the first time in an undisturbed state, with well-nigh half the axial skeleton of a colossus, whose backbone was hitherto known only by some few isolated vertebræ.

The specimen of the Mosasaur is from the famous Kansas Chalk, which vies only with that of Mesvin in yielding the remains of the later aquatic reptiles, as evidenced by the grand series preserved in the Brussels Museum. The specimen under consideration measures some thirty feet in length, and is in detail noteworthy for the condition of its cervical vertebræ and limb skeleton, and